Shade Materials for Modifying Greenhouse Climate

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Abstract

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Contents

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Edwin A. Davis and Frank D. Cole

Background

Alternatives for shading research greenhouses are limited for modifying temperature and light intensity. Two important characteristics of shading materials for a research greenhouse are that they allow alteration of shading patterns and degree of shading, and provide for ease of installation and removal. Temperature regulation is an important function of shading, especially for greenhouses in areas where evaporative cooling is not completely effective.

Several types of shade materials are used for greenhouses. Whitewash paint (Ekblad 1973) is economical and easy to apply, and with careful application, multiple coats may be used to provide a range of light intensities. However, uneven application or large variations in greenhouse light intensity caused by the collection of dirt or loss of paint by rain may be detrimental if any degree of precision in light intensity is required. Also, light intensity cannot be conveniently modified once paint is applied.

A flowing layer of water has been used with some success; some attempts have been made to absorb more of the infrared radiation by adding various compounds to the flowing water (Canham 1964). An advantage of this system is that it could be automated. Initial cost, a requirement for relatively soft water and a filter system, corrosion to metal glazing bars, and the difficulty of preventing leaks were cited as disadvantages.

Wooden lath, another traditional shading material, is difficult to install, initial cost is high, and its appreciable weight may be undesirable on a greenhouse roof (Canham 1964).

Objectives of this study were to determine effects of several types and locations of shading materials on greenhouse temperatures, and on light intensity, distribution, and quality.

Materials and Methods

All studies were conducted in three glass greenhouses, 15 feet wide by 41 feet long, in Tempe, Arizona. Greenhouses were oriented north and south, were parallel, and were 8.5 feet apart.

Shade materials chosen for comparison included Alsynite corrugated fiberglass panels in luminous white, and synthetic fiber shade cloths (fig. 1). The fiberglass panels, installed inside the greenhouse between the rafters, resulted in a light transmission value of approximately 30 percent, or a shade rating of 70 percent. The shade cloths used were Lumite Saran, a green fabric with a rating of 80 percent shade, and Prop-a-lite polypropylene, black fabrics with ratings of 80 and 55 percent shade. Average life for Saran is 6 to 7 years, with a shrinkage factor of 3 to 4 percent. Average life of Prop-a-lite is 10 to 15 years, with a shrinkage factor of less than 1 percent.

The shade cloths were installed either inside the greenhouse on specially installed hangers, or outside, draped over the top and sides of the greenhouse and secured with weights fastened to grommets in the shade cloth.

Temperatures were measured with shielded maximum-minimum mercury thermometers at bench height at the same location in each greenhouse. Thermometers were calibrated against a standard mercury thermometer, and were rotated daily among greenhouses to minimize discrepancies.

Light intensities were measured with a Weston Illumination Meter (Model 756) with its photocell perpendicular to the sun. Solar radiation was measured by a Yellott, Mark IV Sol-A-Meter or a Kipp and Zonen Solarimeter. An ISCO Model SR Spectroradiometer was used to measure light quality.

All data were subjected to analyses of variance and means were tested for significance according to Duncan's New Multiple Range Test.

Results

Effects of Shade Materials on Greenhouse Temperatures

Effects of three types of shading on greenhouse temperatures during winter, spring, and summer are shown in table 1.

Winter.—The average maximum outside temperature during the winter test period, January 12 to March 7, was 62.0°F. Shade comparisons made during the winter months were between no shade, fiberglass panels inside, and Saran 80 percent shade cloth inside. Evaporative coolers were off, and heaters were on at night. The average maximum greenhouse temperature with Saran 80 percent shade cloth inside was 100.6°F, 11.1°F warmer than with fiberglass panels inside, and 7.2°F warmer than the unshaded greenhouse.

With heaters on at night, the average minimum temperatures with fiberglass panels or shade cloth inside were essentially the same; both raised greenhouse night temperatures about 6.6°F above that in the unshaded house.

Figure 1.—Types of shading evaluated:

Fiberglass panels installed inside the greenhouse between the rafters.

Saran 80 percent shade cloth installed inside.

Prop-a-lite 55 percent shade cloth installed outside.

Table 1.--Average greenhouse temperatures (°F, bench height) without shading, with fiberglass panels inside, and with Saran 80 percent shade cloth inside or outside (means in rows not followed by same letter are significantly different at the 5 percent level)

Time of year and temperatures	Sample size	No shade	Shade material and location: Fiberglass panels, inside	Saran 80 percent shade cloth: Inside	Saran 80 percent shade cloth: Outside	Outside air
WINTER (JAN. 12 - MAR. 7)	55					
Coolers off; heaters on at night and off during day; top vents closed at night and open or closed during day, depending on weather						
Maximum temperature		93.4b	89.5a	100.6c		62.0
Minimum temperature		56.0a	62.8b	62.5b		34.7
Difference between inside and outside mean maximum		+31.4	+27.5	+38.6		
SPRING (MAR. 23 - 29)	7					
Coolers and heaters off; top vents open night and day						
Maximum temperature			95.7a	109.7b	88.4a	74.4
Minimum temperature			58.7a	57.3a	57.7a	49.7
Difference between inside and outside mean maximum			+21.3	+35.3	+14.0	
SUMMER (MAY 21 - JULY 25)	66					
Coolers on, with water; heaters off; top vents open night and day						
Maximum temperature			92.8b	94.4c	88.1a	103.9
Minimum temperature			72.1b	69.6a	69.3a	68.4
Difference between inside and outside mean maximum			-11.1	-9.5	-15.8	

Spring.—The average outside maximum daytime temperature for the spring test period, March 23-29, was 74.4°F. Both coolers and heaters were off and top vents were open continuously. Under these conditions, 80 percent shade cloth outside gave an average maximum greenhouse temperature of 88.4°F, 21.3°F cooler than with shade cloth inside, and 7.3°F cooler than with fiberglass panels inside; the latter difference, however, was not significant at the 5 percent level.

Spring greenhouse temperatures at night with heaters off were approximately equal regardless of shading material or its location.

Summer.—During the summer test period, May 21 to July 25, the average maximum outside temperature was 103.9°F. With evaporative coolers on, 80-percent shade cloth outside resulted in the lowest average maximum greenhouse temperature (88.1°F). The average maximum greenhouse temperature with fiberglass panels inside was 92.8°F; with 80 percent shade cloth inside it was 94.4°F.

Minimum greenhouse temperatures with shade cloth inside or outside were essentially equal. Average minimum greenhouse temperatures with fiberglass panels inside were 2.8°F warmer than those with 80 percent shade cloth outside.

Comparison of 55 and 80 Percent Shade Cloths

Two densities of Prop-a-lite polypropylene shade cloth draped over the greenhouses were compared with "no shade" for their effects on greenhouse temperatures during winter and late spring (table 2).

Winter.—During the winter test period, January 21 to February 28, the average maximum outside temperature was 68.0°F. Greenhouse heaters and coolers were off; top vents were closed at night and open during the day. Average high temperatures under 80 percent and 55 percent shade cloths and "no shade" were 3.7, 9.8, and 22.1°F warmer than the average maximum outside temperature. Minimum greenhouse temperatures under the two densities of shade cloth were not significantly different.

Table 2.--Average greenhouse temperatures (°F, bench height) with no shading and with 55 or 80 percent Prop-a-lite shade cloth installed outside (means in rows not followed by same letter are significantly different at the 5 percent level)

Time of year and temperatures	Sample size	No shade	Shade material and location		Outside air
			55 percent shade cloth	80 percent shade cloth	
WINTER (JAN. 21 - FEB. 28)	22				
Coolers and heaters off; top vents closed at night and open during day. Not all days in time interval were included.					
Maximum temperature		90.1c	77.8b	71.7a	68.0
Minimum temperature		47.1a	45.7a	46.2a	39.1
Difference between inside and outside mean maximum		+22.1	+9.8	+3.7	
LATE SPRING (JUNE 1 - 25)	25				
Coolers on, with water; heaters off; top vents open night and day					
Maximum temperature			88.6b	82.2a	101.2
Minimum temperature			66.7a	67.2a	62.4
Difference between inside and outside mean maximum			-12.6	-19.0	

Spring.—The average maximum outside temperature during the late-spring period, June 1 to 25, was 101.2°F. The greenhouse evaporative coolers were on, heaters were off, and top vents were open continuously. The average maximum greenhouse temperature under 80 percent shade cloth (82.2°F) was 6.4°F cooler than that under 55 percent shade cloth. Minimum greenhouse temperatures were not significantly different under the two types of shade cloth.

Light Distribution

Foot-candles (fc) of illumination under fiberglass decreased 35 percent from panel to bench, while illumination under an 80 percent shade cloth remained constant (table 3).

Energy intensity (ly min^{-1}) under fiberglass panels decreased 27 percent from 1 foot beneath the greenhouse ridge to the bench; the decrease was only 12 percent under 80 percent shade cloth, however. The slight decrease in energy intensity under shade cloth measured with the solarimeter but not with the illumination meter may be because the solarimeter was positioned horizontally, whereas the light meter was held perpendicular to the sun's rays.

Spectral Distribution

Spectral distribution curves were measured with and without shading material (fig. 2). It appears that the quality of light produced by fiberglass or Saran shade cloth in the visible portion of the spectrum is adequate for plant growth. No important differences can be seen in comparison with sunlight.

Discussion

An advantage in the use of fiberglass panels is that light is diffused and shadows are eliminated. Disadvantages include darkening with age with some types of fiberglass, including the type used in these tests, and higher greenhouse temperatures than those produced under shade cloth installed outside. Although fiberglass is available in different transmittancies and colors, the panels are not as easy to install, remove, and store as shade cloth. Light intensities under fiberglass varied from roof to bench.

Shade cloth placed outside resulted in the most effective control of greenhouse temperature. Other desirable characteristics are convenience of installation and removal, and the availability of a wide

Table 3.--Effect of fiberglass panels and Saran 80 percent shade cloth on light distribution from greenhouse roof to bench

Distance from roof (ft)	Fiberglass panels				Saran 80 percent shade cloth			
	Illumination[1]		Energy intensity[2]		Illumination[1]		Energy intensity[2]	
	fc	*% decrease*	*ly min*$^{-1}$	*% decrease*	*fc*	*% decrease*	*ly min*$^{-1}$	*% decrease*
0	4,600	0	--	--	2,200	0	--	--
1	4,000	13.0	0.312	0	2,200	0	0.164	0
2	3,600	21.7	.280	10.3	2,200	0	.155	5.5
3	3,400	26.1	.264	15.4	2,200	0	.153	6.7
4	3,200	30.4	.258	17.3	2,200	0	.153	6.7
5	3,000	34.8	.248	20.5	2,200	0	.149	9.1
6	3,000	34.8	.238	23.7	2,200	0	.145	11.6
7	--	--	.228	26.9	--	--	.144	12.2

[1]The photocell of the light meter was held perpendicular to the sun.
[2]Wavelength of the solarimeter was limited by the glass dome to 280-2,500 nm. Measurements were made vertically beneath a top vent when the sun was nearly overhead. The solarimeter was leveled at each height.

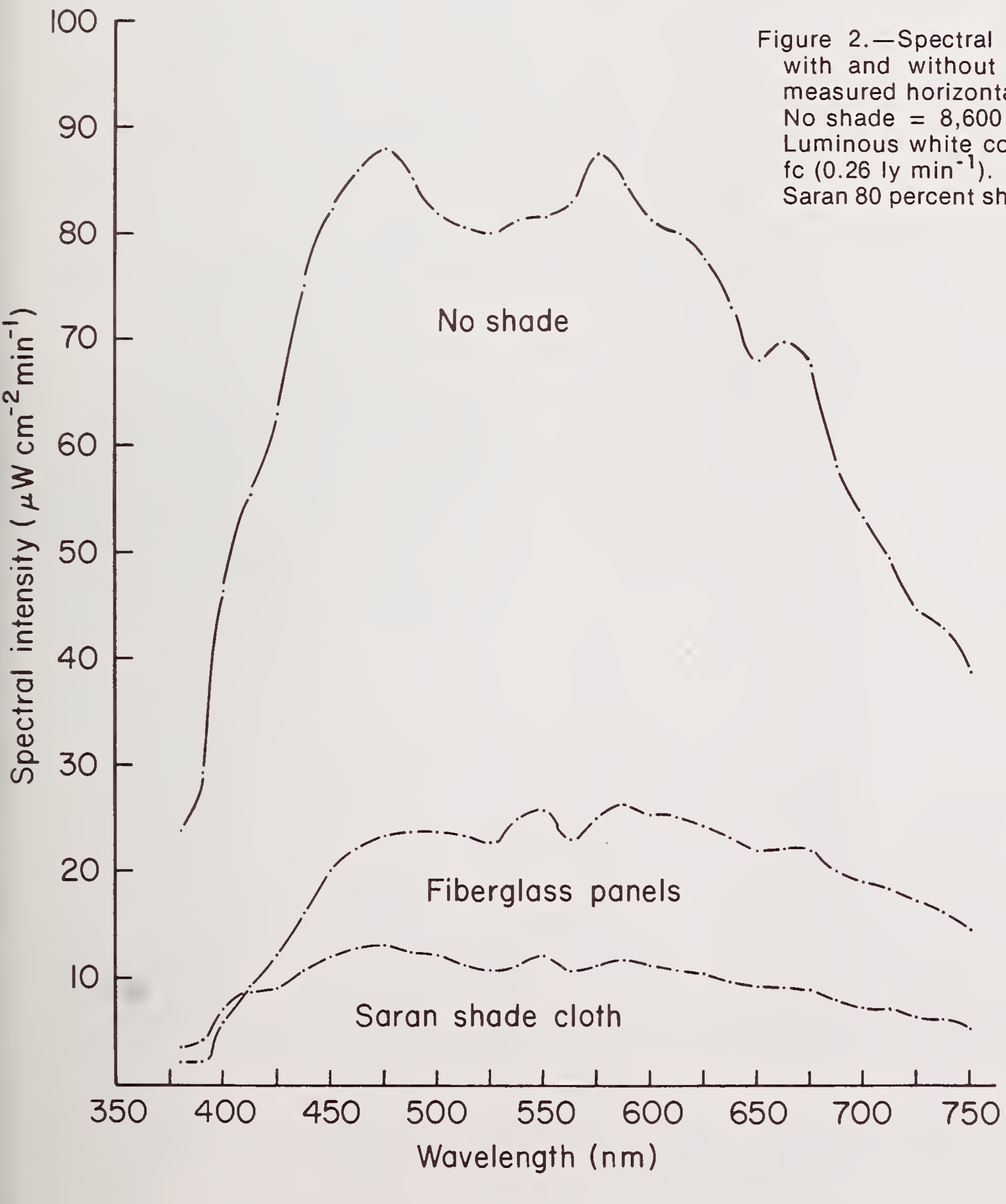

Figure 2.—Spectral distribution curves in greenhouse with and without shade materials. Light intensities measured horizontally were:
No shade = 8,600 fc (0.91 ly min^{-1}).
Luminous white corrugated fiberglass panels = 2,300 fc (0.26 ly min^{-1}).
Saran 80 percent shade cloth = 1,400 fc (0.13 ly min^{-1}).

choice of densities. Light intensities under shade cloth were more uniform from roof to bench than those under fiberglass.

A minor disadvantage of shade cloth installed outside is dirt collection, although it can easily be cleaned by hosing. Inside installation resulted in undesirable increases in daytime greenhouse temperatures when evaporative coolers were off. However, the heat gain associated with inside installation could be used to reduce heating costs during winter.

Light quality produced by shading with luminous white fiberglass and Saran shade cloth is comparable in the visible portion of the spectrum and is adequate for plant growth. Light transmitted by Saran shade cloth, when the shade is less than 75 percent of the available light, has been found to be comparable in quality to that under trees (Gaskin 1965).

Synthetic fabric shade cloths offer more advantages as a shade material for a research greenhouse, especially in areas of high solar insolation such as the southwestern United States, than fiberglass panels, whitewash, or other materials such as lath. They offer ease of installation and removal, are relatively maintenance-free, and are available in a variety of densities for regulating light intensity and controlling temperature.

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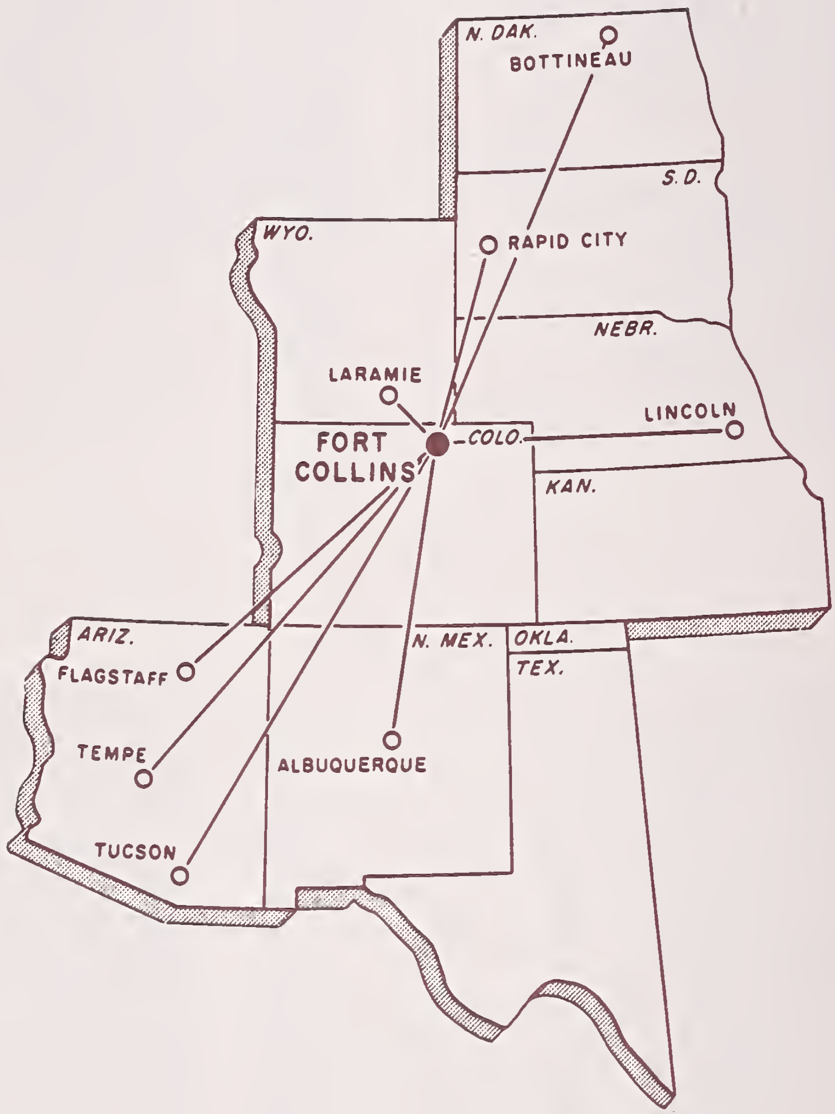
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